Chapter 2: Overview of Flexographic Printing

CHAPTER CONTENTS

INTRODUCTION

This chapter presents an overview of flexographic inks, the printing process used, the market trends, federal regulations that relate to the flexographic printing industry, and safety issues related to the printing process. This information provides some context for interpreting the specific CTSA research that follows.

COMPONENTS OF FLEXOGRAPHIC INKS: Section 2.1 describes the major types of ink components for the three ink systems that were studied — solvent-based, water-based, and UV-cured. These categories include solvents, colorants, resins, additives, and compounds that are unique to UV inks.

MARKET PROFILE: Section 2.2 describes the general flexographic printing market, including sub-categories, market trends, and markets for flexographic inks in particular.

FEDERAL REGULATIONS: Section 2.3 provides an overview of the federal regulations pertaining to environmental releases and workplace safety potentially affecting the flexographic printing industry. This section does not attempt to provide a comprehensive analysis of regulations.

PROCESS SAFETY: Section 2.4 describes safety issues related to the flexographic printing process.

Flexography is an industry in the midst of major changes. Technological advances made in the past decade, combined with compelling market forces, have opened up major new growth areas for flexographic inks and printing. At the same time, regulatory pressures have caused printers and formulators to think carefully about the safety and environmental impacts of flexographic inks and the ways in which they use them.

2.1 INTRODUCTION TO FLEXOGRAPHIC INKS

A functional flexographic ink must exhibit several qualities. It must produce a color or other visual effect. It must adhere to the material being printed (the substrate). It must withstand conditions to which it will be exposed in practical use, such as to chemicals, abrasion, and extreme temperatures. Finally, it must produce a consistent finish.

Different types of ingredients contribute to a successful ink. This section discusses the categories of chemicals that comprise a typical ink product line, and the three general ink systems into which the chemical categories fall.

Ink Components

Five types of components allow ink to adhere to a substrate and produce its visual effect. The solvent provides fluidity, which allows the ink to be transported from the ink fountain to the substrate. The colorant, which can be either a pigment or dye, provides the color associated with ink. The resin causes the ink to adhere to the substrate, among other traits. Additives modify the physical properties of the inks, such as flexibility and the coefficient of friction. Finally, in UV-cured inks, UV-reactive compounds participate in the photochemical reaction that cures the ink.

Solvents
Solvents are important in delivering the ink to the substrate. The solvent allows the ink to flow through the printing mechanism, and then evaporates so that the ink forms a solid coating on the substrate. Typically, inks are manufactured and transported in a concentrated form, and the printer must add solvent to the ink to attain the desired viscosity. A solvent must display several important characteristics. It must adequately disperse or dissolve the solid components of the ink, but must not react with the ink or with any part of the press. It must dry quickly and thoroughly, and have low odor. Finally, it is desirable for the solvent to have minimal flammability and toxicity concerns.

Common solvents in solvent-based inks are ethanol, propanol, and propyl acetate. In water-based inks, the solvent is water, which is amended with alcohols, glycols, or glycol ethers. UV-cured inks are different in that they do not have solvents per se, in that the chemicals are not added with the intention of being evaporated after application of the ink. Fluidity is provided by liquid, uncured components of the ink, such as monomers, which are incorporated chemically into the ink upon curing, instead of evaporating.

Colorants
Colorants are compounds that reflect and absorb certain wavelengths of light. Wavelengths that are reflected by a colorant are seen by the eye and perceived as colors. The two types of colorants used in printing are dyes and pigments. Dyes are soluble in the vehicle, and the final product can be transparent. The most common dyes are basic, amino-based compounds. The transparent properties of dyes can be beneficial when transparency is desired, and the colors of dyes are often quite strong. However, dyes can be susceptible to attack by chemicals and water, and they can also be toxic.

Pigments are small, insoluble particles. They can be made from a wide range of organic and inorganic compounds, and as a result, have a variety of properties. Particle size and chemical stability are two variable properties that can yield differing ink characteristics. In general, pigment-containing inks are more resistant to chemicals and heat and are less prone to bleeding through the substrate than dye-containing inks.

Resins

Resins are solid compounds that are soluble in the solvent and often have complex molecular structures. They cause ink to adhere to the substrate, disperse the pigment, and provide gloss to the finished coating. Resins also can impart differing degrees of flexibility, scuff resistance, cohesive strength, block resistance, and compatibility with the printing plates. Common categories of resins include nitrocellulose, polyamides, carboxylated acrylics, and polyketones.

Additives

Several components can be added to inks to improve the performance of the finished products. Examples include plasticizers, which enhance the flexibility of resins; waxes, which enhance slip, rub and scuff resistance; wetting agents, which modify the surface tension to improve adherence to substrates; and defoaming agents, which in water-based inks reduce soap-like effects.

UV-Specific Compounds

The curing process of UV-cured inks is fundamentally different from that of solvent- and water-based inks. Chemicals in the inks react to form solid polymers upon exposure to ultraviolet light. Three types of compounds are necessary in order for such a reaction to occur: monomers, oligomers, and photoinitiators. Monomers are individual molecular units that can combine to form larger structures known as polymers. Oligomers are small polymers that can be further combined to form larger polymers. A photoinitator uses UV light to enable a chemical reaction to take place. Photoinitiators are often aromatic ketones, and monomers and oligomers are acrylate-based in most commonly used inks.

In free-radical curing (presently the most common commercial form), the photoinitiator fragments into reactive free radicals in the presence of ultraviolet light. These free radicals react with monomers and oligomers, which link together to form a polymer that binds the ink together. The reaction is illustrated in the box below. The photoinitiator (indicated by -CO-R) reacts in the presence of UV light to form a free radical (•R). This free radical then reacts with an acrylic monomer (or oligomer) so that the monomer/oligomer bonds with similar compounds to form a polymer.

$$
\begin{gathered}
-CO-R \xrightarrow{Energy} -CO\bullet + \bullet R \\
\bullet R + CH_2 = CH - COOR \rightarrow -[CH_2 - \underset{|}{C}R - COOR]_n
\end{gathered}
$$

Ink Systems

The primary difference among the three major ink systems is the method used for drying or curing the ink. Solvent-based and water-based inks are dried using evaporation, whereas UV-cured inks are cured by chemical reactions.

Solvent-based Inks

Solvent-based inks were the first printing inks available commercially. Historically they have been very popular because they dry quickly, perform well, and allow printers a wide choice of products. The solvents in these inks, however, are primarily volatile organic compounds (VOCs), which have concerns for health and safety, as they are usually very flammable. Environmentally, VOCs contribute to the formation of ground-level ozone, which is a component of smog and causes respiratory and other health problems. Partly because of these concerns, other types of inks were developed and markets for them began to develop.

Water-based Inks

The primary solvent in water-based inks is water, but it is important to realize that water-based inks also can and usually do contain varying and often substantial percentages of organic solvents and VOCs. The colorants for water-based inks are very similar to those for solvent-based inks, but resins and additives are generally quite different. Water-based inks are often less flammable than solvent-based inks and are thus easier to store and use. Depending on the VOC content, they may also have fewer environmental concerns. However, they may take significantly longer to dry and are often not as easy to use as solvent-based inks.

Ultraviolet-cured Inks

UV-cured inks comprise a comparatively new ink technology in the flexographic printing industry. They are very different from solvent- and water-based inks in that they are cured through chemical reactions rather than drying through evaporation. Because of this, UV-cured inks do not contain traditional organic solvents, which means they do not emit VOCs. However, they do contain many chemicals that have not been tested comprehensively for environmental, health, and safety impacts. Future research is needed on untested UV chemicals. UV inks have found a growing market outlet in narrow-web printing.

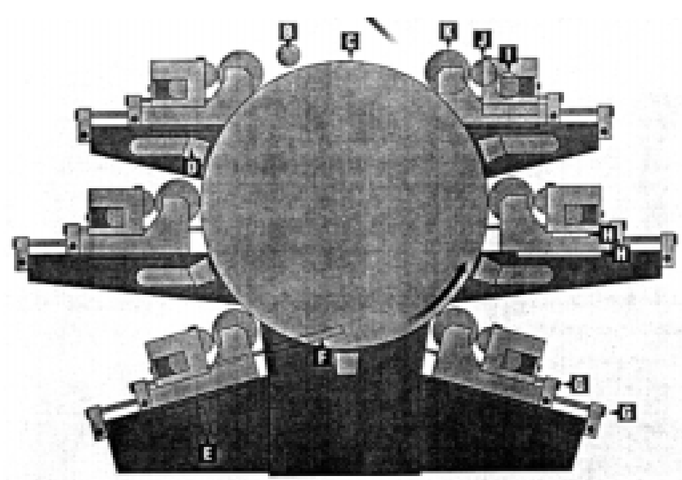
PRINTING WITH A CENTRAL IMPRESSION FLEXOGRAPHIC PRESS

There are three major types of flexographic printing presses: in-line, stack, and central impression (CI). The CI press was selected for use in the CTSA performance demonstrations. In many ways the CI press represents the standard for quality in the flexographic printing industry, especially in converting. This type of press has a particular advantage in holding tight register, which allows it to be used for technically demanding multiple-color jobs on many different substrates. As graphic design in the packaging area has become more complex, flexography has been able to increase its market share largely because of the registration capabilities of the CI press (*Flexography: Principles and Practices,* fifth edition, volume 6, page 7).

The CI press is distinguished and named for its structural configuration (see Figure 2.1), in which different color stations are arranged around a single large (central impression) drum. The number of stations can vary. Most CI presses have six color stations, but presses are now being built with eight and ten stations. The presses used in the CTSA performance demonstrations had six color stations.

The DfE Flexography Project Partners chose to run the performance demonstrations on wide web CI presses with a target width of 24 inches. (Suggested specifications of the presses chosen for the performance demonstrations are given in Appendix 4-A.) The point of choosing this type of press was to allow the Partners to investigate the capabilities of ink systems on film substrates, which represent some of the most complex printing situations and also the anticipated future direction of flexographic printing. Wide web printing in particular can pose many challenges. As a case in point, at the time the Project was being developed, UV-cured inks were making inroads in narrow-web printing but not yet in wide-web printing.

Figure 2.1
Diagram of Central Impression Press (from *Flexography: Principles and Practices,* 5th edition, volume 6, page 6).



2.2 MARKET PROFILE OF THE FLEXOGRAPHIC PRINTING INDUSTRY

Selection of the flexography industry for this study was based, in part, on the vitality of the industry. For several years, flexography has experienced some of the fastest growth among printing industries worldwide, with an average annual growth rate of 6.3%.[1]

In 1997, the U.S. Census reported that the United States had 914 commercial printing establishments in which flexographic printing was the primary print process. These establishments employed 30,550 employees, with a payroll of $1,030,023,000.[2] However, many more facilities — about 2,300 printing facilities in the U.S. — operated flexographic presses.[3]

The proportion of the printing industry that is made up by flexographic printing has steadily grown. In 1994 flexographic printing accounted for 64% of the U.S. printing market share; by 1995 this portion had grown to 75%. In 1996, the flexographic printing industry was a $44 billion dollar industry growing at a rate of 6.3% per year.[4] Wide-web flexography, the segment upon which this CTSA was based, was estimated as a $16 billion industry in 1996,[5] and that grew by an estimated 7% in 1999.[6]

Historically, flexographic printing facilities have been concentrated in the Midwest. These states continue to dominate, but with expansion of the industry, more facilities have opened in California and Texas. Close to 60% of all flexographic facilities are located in ten states: California, Florida, Illinois, Missouri, New Jersey, New York, North Carolina, Ohio, Texas, and Wisconsin.[7]

Flexographic facilities are typically small; approximately 61% have fewer than 20 employees, and roughly 83% have fewer than 50 employees.[8] The smallest facilities tend to focus exclusively on flexographic printing and predominantly operate narrow web presses. The largest facilities tend to operate a combination of graphic arts processes and produce various forms of flexible packaging.[9]

Descriptions of Different Flexography Market Segments

In 1997, the U.S. Department of Commerce introduced a new industry classification system, the North American Industry Classification System (NAICS). NAICS replaced the Standard Industrial Classification (SIC) system as the standard classification system for the United States, Canada, and Mexico. Under NAICS, an industry is generally defined as a group of establishments that have similar production processes. Printing and Related Support Activities is listed under NAICS code 323. Commercial Flexographic Printing is tracked under NAICS code 323112. It is defined as an industry comprised of establishments engaged in flexographic printing, excluding publishing (with certain exceptions, including books and manifest business forms).[10]

The four-digit SIC code 2893 (Printing Ink) is now NAICS code 32591. Flexible packaging segments are also covered by several NAICS codes. Table 2.1 matches the 1997 NAICS codes with the 1987 SIC codes for flexographic printing, flexographic inks, and flexible packaging products. The flexographic inks and printing segments have been highlighted in the table (in grey shading), as these are the primary focus of this CTSA.

Table 2.1 1997 Flexography NAICS Codes Matched with 1987 SIC Codes

NAICS code	1997 NAICS U.S. Description	SIC code	1987 SIC U.S. Description
322	Paper Manufacturing		
322221	Coated and Laminated Packaging Paper and Plastics Film Manufacturing	2671*	Packaging Paper and Plastics Film, Coated and Laminated (single-web paper, paper multiweb laminated rolls and sheets)
322222	Coated and Laminated Paper Manufacturing	2672	Coated and Laminated Paper, Not Elsewhere Classified
		2679*	Converted Paper and Paperboard Products, Not Elsewhere Classified (wallpaper and gift wrap paper)
322223	Plastics, Foil, and Coated Paper Bag Manufacturing	2673*	Plastics, Foil, and Coated Paper Bags (coated or multiweb laminated bags)
322224	Uncoated Paper and Multiwall Bag Manufacturing	2674	Uncoated Paper and Multiwall Bags
322225	Laminated Aluminum Foil Manufacturing for Flexible Packaging Uses	3497*	Metal Foil and Leaf (laminated aluminum foil rolls and sheets for flexible packaging uses)
323	**Printing and Related Support Activities**		
323112	Commercial Flexographic Printing	2759*	Commercial Printing, Not Elsewhere Classified (flexographic printing)
323112	Commercial Flexographic Printing (Continued)	2771*	Greeting Cards (flexographic printing of greeting cards)
		2782*	Blankbooks, Loose-leaf Binders and Devices (flexographic printing of checkbooks)
325	**Chemical Manufacturing**		
325910	Printing Ink Manufacturing	2893*	Bronze Ink, Flexographic Ink, Gold Ink, Gravure Ink, Letterpress Ink, Lithographic Inc, Offset Ink, Printing Ink: base or unfinished, Screen Process Ink, Ink - duplicating
326	Plastics Product Manufacturing		
326111	Unsupported Plastics Bag Manufacturing	2673*	Plastics, Foil, and Coated Paper Bags (plastic bags)
326112	Unsupported Plastics Packaging Film and Sheet Manufacturing	2671*	Packaging Paper and Plastics Film, Coated and Laminated (plastics packaging film and sheet)

*indicates part of a 1987 SIC category

The greatest growth of the flexographic marketplace recently has been seen in the Corrugated, Folding Carton, and Labels segments.[11]

Flexible Packaging

Flexible packaging is defined as any package or part of packaging with a thickness of ten millimeters or less whose shape can be readily changed. Most of the printing of flexible packaging is done by flexographic printing processes. According to the Flexible Packaging Association (FPA), the flexible packaging industry employed 375,000 people, and converters employed 87,000 in 1998.[12] Based on U.S. Department of Commerce census data, FPA estimated that the flexible packaging industry grew 3.2 in 1997 to $17.5 billion (Table 2.2). In 1998, the flexible packaging industry grew by approximately 3% to $18.5 billion and it is forecasted to grow by 6.9% in upcoming years.[13] The President of the Flexible Technical Association stated in May 1999 that about 65% of packaging is accounted for by flexography.[14]

Table 2.2 Relevant Categories for Flexographic Printers in Flexible Packaging

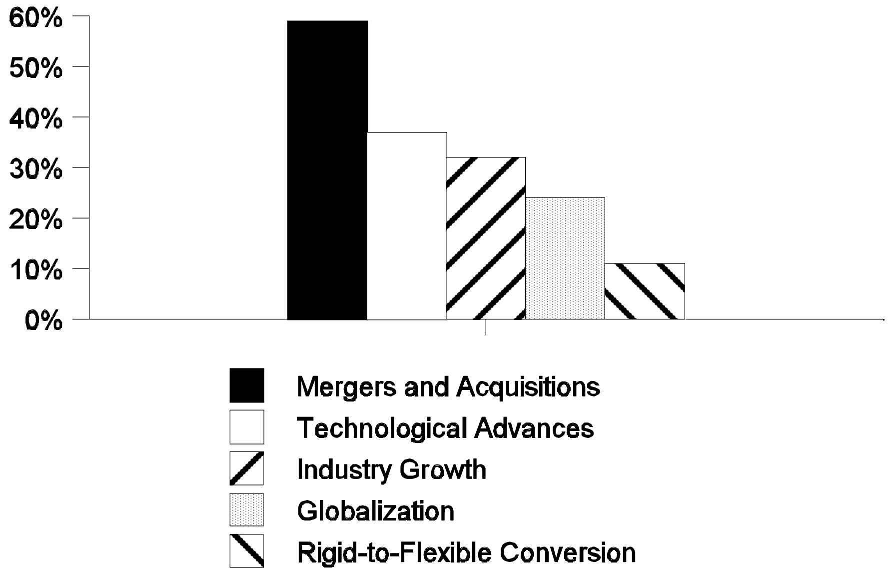
Category	SIC Code	Value of Shipments (1997)[1]	Sample Products
Paper coating and laminating, packaging	2671	$4.5 billion	Bread wrappers, coated or laminated packaging paper, waxed paper for packaging
Bags: plastics, laminated, and coated	2673	$7.5 billion	Frozen food bags, trash bags, plastic merchandise bags
Bags: uncoated paper and multi-wall	2674	$3.0 billion	Paper grocery and shopping bags, glassine bags, un-coated paper merchandise bags
Metal foil and leaf	3497	$2.5 billion	Foil lids in frozen foods, foil laminated to paper or other materials
TOTAL		**$17.5 billion**	

[1]FPA Estimates (FPA, 1998)

The demand for flexible packaging is driven by food products (particularly fresh produce and snack foods), pharmaceutical products, surgical and medical equipment, agricultural products, industrial chemicals, household goods, garden supplies, pet food, cosmetics, and retail merchandise. Food products alone account for 50% of the demand for flexible packaging; medical and pharmaceutical products constitute 25%.

Every year the FPA conducts a survey of its member companies (consisting of printers, converters, packaging companies, packaging schools, and other related companies), to obtain industry statistics. In its 1998 Outlook Survey respondents (94 companies) were asked what they thought the outlook for their industry might be in the next five years. Figure 2.1 shows highlights of the 1998 responses. (Categories total more than 100% because respondents could mention multiple issues.)

Figure 2.1 Flexible Packaging Industry's 1998 Vision of Next 5 Years



Source: FPA, 1998 Outlook Survey

Tags and Labels
Flexography dominates the market for tag and label printing, which has surged over the past decade. Labels and tags comprised $9 billion in 1998, or 9% of the North American packaging market.[15]

Corrugated Containers
Corrugated containers provide an economical source of strong, versatile packaging. Corrugated board is typically made of kraft linerboard, which uses virgin, unbleached, softwood pulp. The corrugated container industry is one of the largest industries utilizing flexographic printing. In 1996, the corrugated container industry was a $18 billion industry.[16] It is also one of the fastest-growing industries, with an average annual growth rate of 6% between 1993 and 1998.[17]

Corrugated materials are characterized by irregularities, which in the past made it difficult or expensive to print high-quality graphics directly on the corrugated board. As the role of corrugated packaging has expanded from simply protecting its contents for transport and handling to generating customer interest at the point of sale, technology has also improved. By the late 1990s, flexographic printers could print directly on corrugated substrates while maintaining high print quality, thereby increasing the use of corrugated containers.

Flexography prints 14 million tons of corrugated material each year, exceeding all other paper/paperboard end-use markets such as folding cartons, paper cups, milk cartons, and envelopes.[18] In 1996, corrugated containers accounted for 45% of the flexographic printing market. Flexography accounted for 20% of the folding carton sector alone in 1997, and this was expected to increase to between 30% and 40% by the year 2000.[19]

Market-Related Trends in the Flexographic Printing Industry

As print quality has improved, flexographic printing has successfully penetrated additional printing markets. Between 1995 and 1997 the most dramatic changes were seen in the Tags, Tapes and Labels segment. In 1995 only 55% of these products were printed by flexography; by 1997 this number increased to 75%. The most dramatic decrease occurred in the Folding Cartons segment; printing of these products by flexography dropped from 40% to 15-20% between 1995 and 1997. This may be due to the shift in the packaging industry from rigid to flexible packaging.

Industry experts predict that flexographic market share will grow to 20% in coming years.[20] A variety of technical, economic, and industry marketing factors account for this anticipated growth, as described in the following paragraphs.

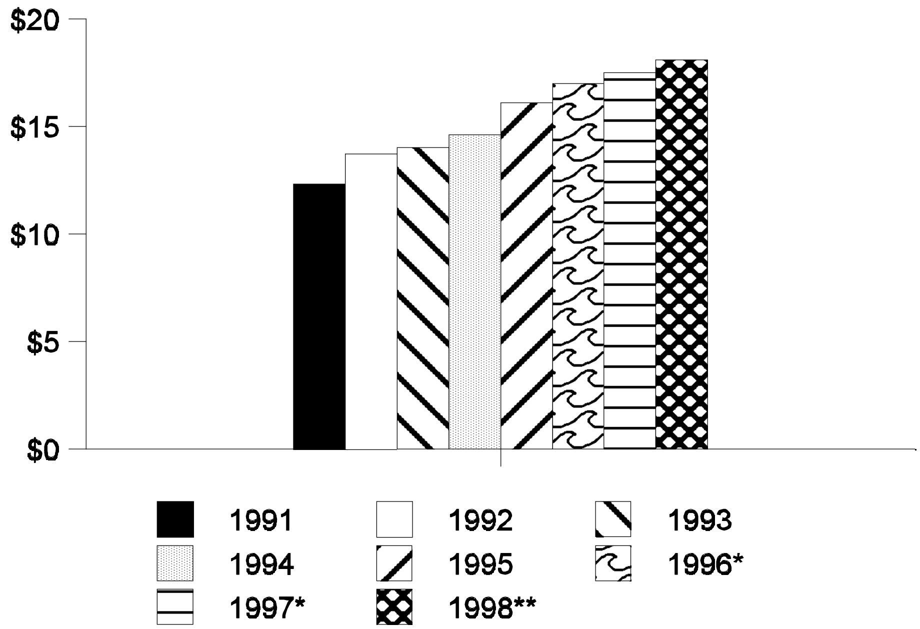
Improved quality of flexographic printing: Early print quality of flexography was typically inferior to that of lithography and gravure. Technological advances have greatly improved the quality of flexography, leading to greater use of color and more sophisticated and colorful design. These technological improvements in flexographic printing have resulted in increased acceptance of flexography by print buyers.

Increased demand for flexographic printing: Because of quality improvements and lower costs, flexography is expected to take some market share away from other printing segments.

Expanded applications for flexible packaging: In recent years there has also been a shift from rigid packaging (e.g., cardboard boxes, glass) to soft packaging. This in turn has increased the need for printing of flexible packaging of fresh produce, drugs, surgical/medical, snack foods, and agricultural products/industrial chemicals.[21]

It is expected that demand for flexible packaging will continue to increase, leading to increasing growth in the use of flexographic inks and printing processes. The flexible packaging industry was expected to grow by an estimated 3.7% to $18.1 billion in 1998. Figure 2.2 illustrates the growth in the flexible packaging industry between 1991 and 1998.[22]

Figure 2.2 Size of Flexible Packaging Industry, 1991-1998
(Billions of Dollars)



*FPA Estimate **FPA Forecast Source: FPA, 1998

Shorter print runs with more variability and faster delivery: Increasing market segmentation, and significant technological improvements in the flexible packaging and printing industries, have caused many industries to expand the alternatives within a product line. For example, potato chip manufacturers may market a variety of products such as “light”, “low salt”, and “barbecue”, where there once was only one product. This trend has also led to more applications for pressure-sensitive labels.[23]

Another aspect of this trend has been a move toward shorter printing turnaround and faster delivery. Packaging now acts as “on-the-shelf” promotion, requiring shorter runs for specialized products. With comparable quality and lower cost of printing plates, flexography is able to respond to the demands for shorter, more frequent runs more economically than the gravure and lithographic processes.

Expanded variety of products: In recent years the combination of general economic growth and improvements in the flexible packaging and flexographic printing quality have led to greater use of flexography for printing a wide variety of packaging, including packaged fresh foods, convenience foods, drugs, surgical and medical products, and agricultural and industrial products and chemicals.

Digital Technology: Recent, rapid growth in digital prepress and output technology have created a variety of new markets and applications for digitally printed products.

Other factors that will tend to influence the future of flexographic printing include:

- Growth of new electronic “publication” venues, such as the Internet

- Regulatory issues
- Continued mergers and acquisitions
- Rapidly increasing competition
- Globalization of trade

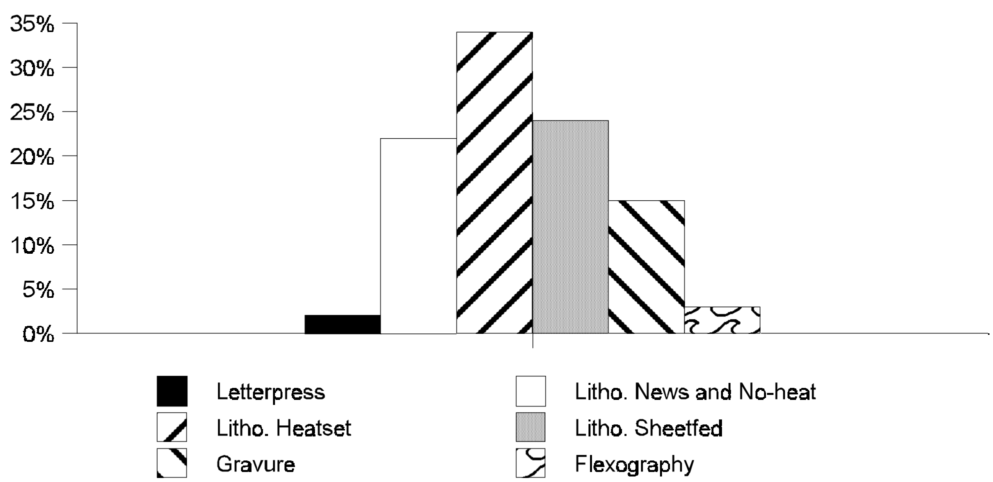
The combined long-term effects of all these trends are not clear, but some industry experts predict potentially difficult times ahead for small printers and those that do not continue to confront the rapidly changing marketplace of the future.

Markets for Printing Inks Overall

The use of flexographic inks has been increasing faster than that of any other ink type, a trend that is expected to continue. According to *Ink World* magazine, in 1997 the flexographic ink market was growing at a rate of 6-8% annually, with the largest gains in the Corrugated, Folded Carton and Labels sectors.[24] Flexographic inks represented 18% (about $720 million) of the $4 billion printing ink market in 1997.[25]

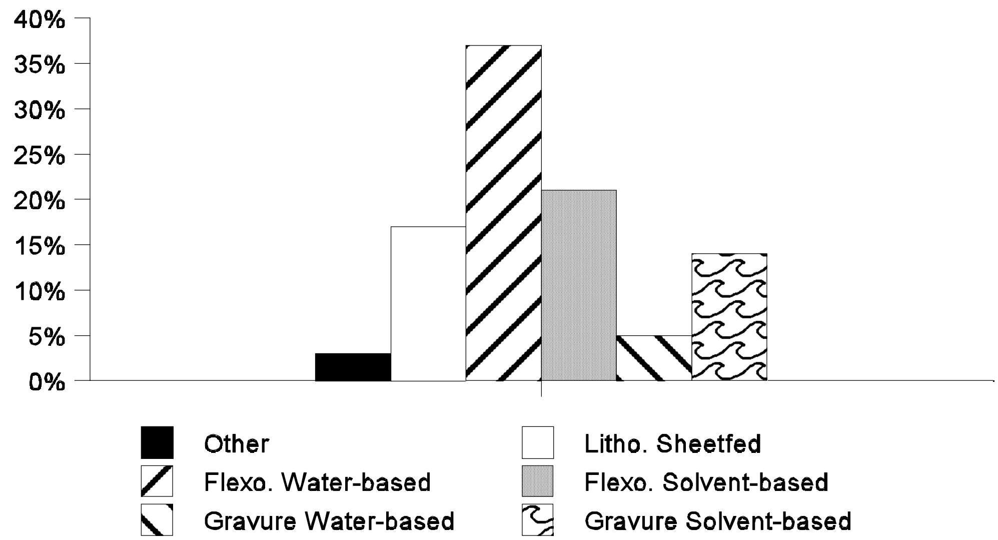
The largest consumers of printing ink overall in 1998 were the publication and commercial segments of the printing industry, followed by the packaging ink segment.[26] In 1998, flexographic inks made up 58% of the packaging ink segment but only 3% of the publication and commercial printing ink segment (Figures 2-3 and 2-4).

Figure 2-3 Market Composition of the Publication and Commercial Printing Ink Segment (1998)



Source: NAPIM, 1999

Figure 2-4 Market Composition of the Packaging Ink Segment (1998)



Source: NAPIM, 1999

According to industry reports, 1995 -1998 were difficult years for ink manufacturers.[27] Faced with increasing raw material costs and aggressive pricing strategies by the largest manufacturers, many manufacturers experienced decreases in sales growth. Raw material costs have been a particular problem for the industry since prices began to rise dramatically in 1994. Raw material costs accounted for 57% of the value of shipments in 1995 and 1996.[28]

In the past few years the printing ink industry has experienced a very active period of mergers and acquisitions, reflecting a similar trend in flexography. This is reflected in the volume of sales for the largest ink companies. As shown in Table 2.3, Sun Chemical had more than three times the 1997 sales dollars than the number 2 company, Flint Ink. The top 20 companies in Table 2.5 totaled $3,940 million in 1997 sales.

Table 2.3 Leading U.S. Ink Manufacturers in 1997

Rank	Company	Location	Sales ($million)
1	Sun Chemical	Fort Lee, NJ	2,000[a]
2	Flint Ink	Detroit, MI	625
3	INX International	Elk Grove Village, IL	310
4	The Ink Company	W. Sacramento, CA	125
5	Alper Ink Group	New York, NY	120
6	Siegwerk	Lynchburg, VA	80
7	Superior Printing Ink	New York, NY	78
8	Heritage Inks International	Edison, NJ	62
9	SICPA Industries of America	Springfield, VA	60
10	Van Son Ink Corp. (of America)	Mineola, NY	60
11	Wikoff Color Corp.	Fort Mill, SC	59
12	Nazdar	Shawnee, KS	57
13	Color Converting Industries	Des Moines, IA	49
14	Handschy Industries	Bellwood, IL	41
15	Coates Brothers Inc.	Rutherford, NJ	40
15	Toyo Ink America	Englewood Cliffs, NJ	40
17	Braden Sutphin Ink Co.	Cleveland, OH	38
18	Louis Werneke Co.	Plymouth, MN	35
19	Central Ink	West Chicago, IL	31
20	Manders Premier	Niles, IL	30
	Total sales of top 20 firms		**3,940**

Source: *Ink World*, April 1997.
[a]$2 billion in worldwide printing ink sales. $1 billion in North American ink sales, including revenues from General Printing Ink (GPI), US Ink, and Kohl & Madden.

Markets for Flexographic Ink Systems

The Solvent-based Ink System

Solvent-based inks are widely used in many flexographic printing processes. They are generally considered to be the industry standard for ease of use and quality of printing. However, use of solvent-based inks has raised a number of environmental concerns, and other ink systems were developed partly to improve on some of these concerns.

The Water-based Ink System

Water-based inks were first used to print kraft linerboard for decorative corrugated cartons. Improvements in the printability of water-based inks paralleled concerns about environmental regulations related to use of solvent-based inks. This spurred the increased use of water-based inks in many other areas of flexographic printing. In 1998, water-based inks made up 51% of the printing inks consumption ($435 million of $850 million total) and 60% of the volume of all flexographic inks.[29] In 1999 all newsprint was printed with water-based inks,[30] about 30% of all film was printed with water-based inks, and wide-web printing consisted of 51% water-based inks.[31] Water-based inks are now used to print 80% of the total market of printing films, corrugated, paper and paperboard, low-end giftwrap.[32]

The UV-cured Ink System

Packaging that comes in direct contact with food and medicine usually has not been printed with UV-cured inks because of the odor from any uncured ink and because of the potential for monomers in the ink to migrate through the packaging to the product. Newer developments have improved UV technology in both areas, and UV flexographic printing may eventually stake a market share in this lucrative segment of packaging. Cationic inks, because they cure more thoroughly, could play a significant role in expanding these markets.[33]

The decrease in the amount of photoinitiator (the most expensive component) required for UV technology, and the increasing size of the market for UV inks (especially in the narrow-web field), are causing the price of UV inks to drop. The use of UV inks has also been steadily increasing. The use of UV flexographic inks grew by 12% in 1999.[34] This technology has gained a strong foothold in narrow-web labels and tags. By 1998 UV accounted for at least $85 million in ink consumption.[35]

This combination of factors is expected to cause UV curing to continue to grow in market share, and to make some inroads into wide-web printing.

However, the technology to remove VOCs and other harmful chemicals from solvent-based ink emissions improved markedly during the 1990s. In addition, regulators began to apply environmental regulations to water-based ink emissions as well as to solvent-based inks. Partly for these reasons, the market for UV inks has not increased as rapidly as was once expected.

Table 2.4 lists the dollar volume of inks used by different flexographic product markets. One of the largest industries to use flexographic inks is the packaging industry, which uses 90% of flexographic inks.[36] Table 2.5 shows the quantity and value of product shipments of flexographic inks in 1997. The total value of shipments of flexographic inks in that year was $703.1 million.

Table 2.4 Use of Flexographic Inks by Product Category

Product	1994 Ink Use ($ million)[a]
Flexible Packaging	290
Corrugated Containers	150
Food Containers	50
Labels/Envelope/Commercial Printing	45
Bags	40
Newspaper	25
Household Paper	20
Miscellaneous	20
Wall Coverings	15
Rigid Plastics	10
Folding Cartons	10
Total	675

[a] Wainberg, Peter. 1995. "Not Only Flexo Ink...But Technology." *FLEXO*, June 1995.

Table 2.5 1997 Shipments of Flexographic Inks

Ink type	Product Shipments Value (million dollars)
Solvent-based	160.5
Water-based	334.2
News and Commercial	102.4
Other Flexographic	50.6
Flexographic , n.s.k.[b]	55.4
Total	703.1

Source: U.S. Department of Census, 1999.
[a] NAPIM, 1998.
[b] Not specified by kind.

Imports and Exports for Flexographic Inks

Exports of colored flexographic inks have been rising over recent years, but import volume decreased significantly in 1999.

NAPIM estimated 1998 total U.S. printing ink exports at 52 million kilograms (about 115 million pounds), a 9.7% increase over 1997. Major destinations for exports of U.S. printing inks include Canada, South America, Asia/Pacific, Europe, Mexico, Central America, and the Carribean. Exports to Mexico grew by 76.4% between 1997 and the first 11 months of 1998.[37] This may be due to the increased trade opportunities made available through the North American Free Trade Agreement (NAFTA).

Exports of black flexographic inks dropped by about 50% between 1998 and 1999 (2,406,900 kilograms in 1998 to 1,166,040 kilograms in 1999). Exports of colored flexographic inks increased by 16% from 8,342,930 kilograms in 1998 to 9,671,620 kilograms in 1999.

The United States imports printing inks from Japan, Canada, Germany, the Netherlands, the United Kingdom, and Mexico. In 1998 the United States imported 20 million kilograms of printing inks, including 638,660 kilograms of black flexographic ink (NAPIM, 1999). In 1999, however, imports of black ink fell by more than 50% to 301,770 kilograms. Imports of other colors of flexographic inks also fell by 25%, from 2,521,000 kilograms in 1998 to 1,893,370 kilograms in 1999.[38]

2.3 FEDERAL REGULATIONS

This section describes federal environmental, health, and safety regulations that may affect the use of flexographic printing chemicals and inks. Regulatory requirements have significant effects on costs, equipment requirements, overhead, and owner/operator liability.

Flexographic printers may be subject to some of the following federal laws:

- Clean Air Act (CAA)
- Resource Conservation and Recovery Act (RCRA)
- Toxic Substances Control Act (TSCA)
- Clean Water Act (CWA)
- Safe Drinking Water Act (SDWA)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Emergency Planning and Community Right to Know Act (EPCRA)
- Occupational Safety and Health Act (OSH Act)

Federal environmental laws often provide for implementation by federally approved, authorized, or delegated state or local agency programs. These programs must be at least as stringent as the federal programs, and may be more stringent. There may also be additional state or local requirements that have no federal counterpart. This summary discusses only federal laws, and only covers ink chemicals referenced in this CTSA. Therefore, readers should be aware of state and local regulations, and requirements associated with chemicals not used in this CTSA. Also, this section only discusses regulations applicable to the flexographic printing process; other activities undertaken in a printing facility (such as prepress processes) may involve other requirements. A list of additional sources for regulatory information can be found in the box at the end of this section.

Clean Air Act

Air regulations represent the major environmental challenge for flexographic printers. The Clean Air Act (CAA) and amendments were established to protect and improve air quality and reduce damage to human health and the environment by air pollutants.

Three components of the Clean Air Act are particularly relevant to printers: the National Ambient Air Quality Standards (NAAQS), National Emission Standards for Hazardous Air Pollutants (NESHAP), and permitting.

National Ambient Air Quality Standards (NAAQS)
The National Ambient Air Quality Standards (NAAQS) set maximum concentration limits for six air pollutants. The most relevant to printers is ozone, which is the principal component of smog and is created in part by volatile organic compounds (VOCs) released from inks. Each state must develop a State Implementation Plan (SIP) that identifies sources of pollution for these six pollutants and determines what reductions are required to meet the NAAQS. If the region violates the standard for ozone, it is classified as a nonattainment area. Depending on the degree of nonattainment, specific pollution controls, such as those described in the Control Technology Guidelines (CTGs), may be mandated for sources with potentially uncontrolled VOC emissions. The three basic control guidelines developed for flexographic and gravure printing are the following:

- Use of add-on controls such as thermal and catalytic oxidizers, carbon absorption, or solvent recovery, with a reduction rate of 60%.
- Use of water-based inks that contain at least 75% by volume water and at most 25% by volume organic solvents.
- Use of high-solids inks that have a solvent content of no more than 40% by volume.

National Emissions Standards for Hazardous Air Pollutants

EPA has promulgated National Emission Standards for Hazardous Air Pollutants (NESHAPs) for the printing and publishing industry. (These cover wide-web flexography and rotogravure.) Section 112 of the CAA requires EPA to establish NESHAPs for all major source categories of stationary sources that emit any of the 188 Hazardous Air Pollutants (HAPs) listed in the CAA. HAPs are listed for regulation because they present, or may present, a threat of adverse human health effects or adverse environmental effects. The CAA defines major sources as those that emit, or have the potential to emit, 10 tons per year of any one HAP or 25 tons per year of any combination of HAPs.

NESHAPs require regulated sources to meet emission standards which represent the maximum degree of reduction in emissions that EPA determines is achievable for sources in the category. Such standards are known as Maximum Achievable Control Technology Standards or MACT. In addition to meeting the emission standard, the source must maintain records, file reports, and correctly install, use, and maintain monitoring equipment.

Each affected wide-web flexographic printing facility must limit monthly HAP emissions to one of the following measures:

- five percent of the organic[a] HAPs
- four percent of the mass of inks, coatings, varnishes, adhesives, primers, solvents, reducers, thinners, and other materials
- twenty percent of the mass of solids, or
- a calculated equivalent allowable mass based on the organic HAPs and solids contents of the inks, coatings, varnishes, adhesives, primers, solvents, reducers, thinners, and other materials

These limits can be achieved by substituting non-toxic chemicals for organic HAPs, installing traditional emissions capture and control equipment, or implementing some combination of these two compliance options.

Five HAPs are found in the inks used for this CTSA, and are listed in Table 2.6. Additionally, Section 112(r) of the CAA lists chemicals that are acutely toxic or flammable. If a CAA 112(r) chemical is held in a process in a quantity above the applicable threshold level, the facility must establish a Risk Management Program to avoid the accidental release of the chemical. One chemical used in this CTSA, ammonia, is regulated under CAA 112(r), with a threshold of 10,000 (or 20,000 pounds in the case of ammonia hydroxide).

Permitting

Printers may be required to obtain two types of permits related to air emissions: construction and operating. Construction permits are issued by state or local agencies; they are required when building a new facility, and may be required when installing new equipment such as a printing press. It may be necessary to obtain a construction permit before beginning pre-

[a] Organic HAPs are a subset of VOCs that excludes certain inorganic compounds.

construction activities such as moving existing equipment, pouring concrete, or making arrangements for utility connections.

Many printers also are required to obtain operating permits. One kind of operating permit is that issued by state or local agencies. They may contain enforceable operating conditions and control requirements, as well as recordkeeping and reporting requirements.

Under Title V of the Clean Air Act Amendments of 1990, major sources are required to obtain a Title V operating permit. Major sources are facilities that have the potential to emit 10 tons per year or more of any individual HAP, 25 tons per year or more of any combination of HAPs, or 100 tons per year or more of any air pollutant classified as a VOC. The thresholds are lower for facilities in ozone nonattainment areas. Permit applications include a period of review by the public, neighboring states, and EPA. Permit requirements include emissions monitoring, record keeping, reporting, and all of a facility's other CAA requirements.

Under certain conditions, an alternative to Title V permits may be available. These Federally Enforceable State Operating Permits (FESOPs) limit emissions from a facility to below the Title V thresholds. FESOPs are generally less complicated than Title V permits and are issued by states but can be enforced by EPA.

Table 2.6 CTSA Chemicals Regulated Under CAA

Chemical	112(b) Hazardous Air Pollutant	112(r) Risk Management Plan
Ammonia[a]		✔
Butyl carbitol	✔	
Ethyl carbitol	✔	
Styrene	✔	

[a] In concentrations greater than 20%.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) governs the management of hazardous waste. Hazardous waste can be identified as *characteristic* (ignitable, corrosive, reactive, or toxic) or as a specific *listed* waste (e.g., certain spent solvents, such as toluene). (See Section 2.4, Process Safety Assessment, for an explanation of characteristic wastes.) The major solvents used by flexographic printers are categorized as ignitable. Hazardous wastes must be treated, stored, and disposed of only by approved methods, and require strict recordkeeping.

RCRA hazardous wastes are categorized by codes. Characteristic wastes are indicated by a "D" code. There are four categories of listed hazardous wastes, two of which are most relevant to the printing industry:

- The F list designates particular wastes from certain common industrial or manufacturing processes. They are wastes from non-specific sources, because processes producing these wastes can occur in different industries. This list includes certain spent solvents.

- The U list includes hazardous pure or commercial grade formulations of certain specific unused chemicals. These wastes include product that has been accidentally spilled or cannot be used because it does not meet specifications.

Some chemicals appear under multiple lists, depending on their use; for example, ethyl acetate is associated with waste codes U112 (as a product waste) and F003 (as a spent solvent waste). Table 2.7 lists chemicals used in this CTSA that may be regulated under RCRA.

Table 2.7 CTSA Chemicals Regulated Under RCRA

Chemical	D Waste Code[a]	F Waste Code	U Waste Code
Barium	D005		
Ethyl acetate	D001	F003	U112
Ignitable solvent-based inks	D001		
Isobutanol	D001	F005	U140

[a] Characteristic wastes (D code) are regulated as hazardous wastes when they exhibit the characteristic (e.g., ignitable if the flashpoint is below 140^{o}F) or contain the toxic constituent at levels above the level of regulatory concern.

Hazardous waste generators are subject to one of three sets of requirements, depending on the volume of hazardous waste generated:

- Large Quantity Generators (LQG) generate greater than 1000 kg (approximately 2200 lbs) of hazardous waste per month or greater than 1 kg (2.2 lbs) of acutely hazardous waste per month.

- Small Quantity Generators (SQG) generate between 100 kg (approx. 220 lbs.) and 1000 kg (approx. 2200 lbs.) of hazardous waste per month and less than 1 kg of acutely hazardous waste per month.

- Conditionally Exempt Small Quantity Generators (CESQG) generate no more than 100 kg (approx. 220 lbs.) of hazardous waste per month and less than 1 kg (2.2 lbs.) of acutely hazardous waste per month.

CESQG requirements include hazardous waste identification, waste counting to determine generator status, maximum quantity limits, and a requirement to treat or dispose of waste on-site or at specified off-site facilities. SQG and LQG requirements also include storage unit specifications, personnel training, recordkeeping, and contingency plans. See Table 2.8 for more information on the requirements for each generator status level. The substitution of materials that do not result in hazardous waste generation can reduce or eliminate RCRA requirements.

Table 2.8 Requirements for RCRA Generators

Requirement	CESQG	SQG	LQG
EPA ID Number	Not Required	Required	Required
On-site Accumulation Quantity	≤1,000 kg (~2,200 lbs.); ≤1 kg (2.2 lbs.) acute; 100 kg (~220 lbs.) acute spill residue	≤6,000 kg (~13,200 lbs.)	No Limit
Accumulation Time Limits	None	≤180 days or ≤270 days (if >200 miles)	≤90 days
Storage Requirements	None	Basic requirements with technical standards for tanks or containers	Full compliance for management of tanks, containers, drip pads, or containment buildings
Off-site Management of Wastes	State approved or RCRA permitted/interim status facility	RCRA permitted/interim status facility	RCRA permitted/interim status facility
Manifest	Not Required	Required	Required
Biennial Report	Not Required	Not Required	Required
Personnel Training	Not Required	Basic Training Required	Required
Contingency Plan	Not Required	Basic Plan	Full Plan Required
Emergency Procedures	Not Required	Required	Required
Transport Requirements	Yes [if required by U.S. Department of Transportation (DOT)]	Yes	Yes

Source: U.S. EPA, *RCRA, Superfund & EPCRA Hotline Training Module: Introduction to Generators*, 1999.

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA), enacted in 1976 and subsequently amended, gives EPA a broad mandate to protect health and the environment from unreasonable chemical risks, to gather information, to identify harmful substances, and to control those substances whose risks outweigh their benefits to society and the economy. TSCA provides EPA the authority to regulate activities conducted by manufacturers, importers, processors, distributors, users, and disposers of chemical substances or mixtures. The major sections of interest to flexographic ink formulators and printers are described below.

Section 4

Section 4 authorizes EPA to require testing of certain chemical substances or mixtures identified as risks to determine their effects on human health or the environment. The TSCA Master Testing List is a list of chemical substances for priority testing consideration. Its major purposes are to 1) identify regulatory and voluntary chemical testing needs, 2) focus limited EPA resources on those chemicals with the highest priority testing needs, 3) publicize EPA's testing priorities for industrial chemicals, 4) obtain broad public comments on EPA's testing program and priorities, and 5) encourage initiatives by industry to help EPA meet those priority needs.

Section 5

Section 5 requires manufacturers and importers of new chemical substances (substances not previously listed on the TSCA Inventory) to submit a Premanufacture Notice to EPA 90 days prior to nonexempt commercial manufacture or import. Similar reporting is required for those existing chemical substances (substances listed on the TSCA Inventory) for which certain activities have been designated as a "significant new use." Upon reviewing these notices, EPA may 1) issue an order or rule regulating the manufacture, use, or disposal of the substance, 2) require a manufacturer, importer, or processor of the new chemical or a chemical for a significant new use to develop test data, and/or 3) promulgate a rule identifying significant new uses of the substance.

Section 5 and Acrylate Esters

A Significant New Use Rule (SNUR) was proposed for acrylate esters, which are found in some flexographic ink formulations. However, EPA withdrew the proposed SNUR after receiving, under the terms of a voluntary agreement, toxicity data from acrylate manufacturers that determined that neither triethylene glycol diacrylate nor triethylene glycol dimethacrylate were considered carcinogenic. As a result, EPA no longer supports the carcinogen concern for acrylates as a class. However, EPA may still regulate and maintain health concerns for certain acrylates on a "case-by-case" basis when they are structurally similar to substances for which EPA has supporting toxicity data or when there are mechanistic/toxicity data supporting the concern. Data from experimental studies show some acrylates can cause carcinogenicity, genotoxicity, neurotoxicity, reproductive and developmental effects, and respiratory sensitization. For dermal exposure, EPA continues to recommend the use of protective equipment, such as impervious gloves and protective clothing, for workers exposed to new or existing acrylates and methacrylates. For inhalation exposure, NIOSH-approved respirators or engineering controls to reduce or eliminate workplace exposures should be used. EPA continues to evaluate the acrylate chemical category for ecotoxicity.

Section 6

Section 6 provides EPA with the authority to regulate the manufacture, processing, distribution in commerce, use and disposal of chemical substances or mixtures determined to pose an unreasonable risk to health or the environment. EPA may prohibit or limit the manufacture, processing, distribution in commerce, use, or disposal of a substance. Action can range from a complete ban to a labeling requirement.

Section 8

Under section 8(a) of TSCA, EPA has promulgated regulations at 40 CFR part 712, subpart B (the Preliminary Assessment Information Rule (PAIR)), which established procedures for chemical manufacturers and importers to report production, use, and exposure-related information on listed chemical substances. Any person (except a "small manufacturer or importer") who imports or manufactures chemicals identified by EPA in this rule must report information on production volume, environmental releases, and certain other releases. Small manufacturers or importers may be required to report such information on some chemicals. TSCA section 8(a) affects large ink manufacturers with total annual sales from all sites owned or controlled by the domestic or foreign parent company at or above $30 million for the reporting period, and who produce or import 45,400 kilograms (100,000 pounds) or more of the chemical (see 40 CFR 712.25(c)).

Sections 8(a) and (b) and the implementing regulations, 40 CFR part 710, require EPA to compile, maintain and publish a list of all chemical substances manufactured in, imported into, or processed in the United States (the TSCA Inventory). Certain chemical manufacturers and importers are required to regularly report additional information necessary to allow EPA to maintain the inventory (TSCA Inventory Update Rule).

Under EPA's section 8(c) regulations at 40 CFR part 717, manufacturers, importers and processors must maintain records of significant adverse reactions to health or the environment for which certain allegations of harm have been made by plant personnel, consumers, or the surrounding community. See 40 CFR 717.5 to determine if these requirements apply to flexographic printing industry chemicals. A word of caution: an allegation may be of such a serious nature as to be considered an 8(e) notification.

Under section 8(d) of TSCA, EPA has promulgated regulations that require any person who manufactures, imports, or, in some cases, processes (or proposes to manufacture, import, or, in some cases, process) a chemical substance or mixture identified under 40 CFR part 716 must submit to EPA copies of unpublished health and safety studies with respect to that substance or mixture.

Section 8(e) provides that any person who 1) manufactures, imports, processes or distributes in commerce a chemical substance or mixture, and 2) obtains information which reasonably supports the conclusion that such substance or mixture presents a substantial risk of injury to health or the environment must immediately report that information to EPA unless the person has actual knowledge that EPA has been adequately informed of such information.

Section 12

Section 12 requires exporters of certain chemical substances or mixtures to notify EPA about these exports and EPA, in turn, must notify the relevant foreign governments.

Section 13

Section 13 requires importers of a chemical shipment to certify at the port of entry to the U.S. that either 1) the shipment is subject to TSCA and complies with all applicable rules and orders thereunder, or 2) the shipment is not subject to TSCA.

The Chemical Right-to-Know Initiative and the High Production Volume Challenge Program

The Chemical Right-to-Know Initiative was launched in 1998 in response to studies by the Environmental Defense Fund, the American Chemistry Council, and EPA that found that most commercial chemicals have very little, if any, toxicity information on which to make sound judgements about potential risks. Three key components of the RTK Initiative are to:

- complete baseline testing on the most widely used commercial chemicals
- conduct extensive testing on chemicals to which children are disproportionately exposed
- collect TRI release information on high-priority PBT (persistent, bioaccumulative, toxic) chemicals

The ultimate goal of the RTK Initiative is to make this information publicly available so that the public can make informed choices and decisions about their health and local environment.

EPA challenged industry to voluntarily undertake testing on 2,800 HPV (high production volume) chemicals for which baseline data are not available. HPV chemicals were defined as those manufactured in, or imported into, the US in amounts equal to or exceeding 1 million pounds per year (based on 1990 Inventory Update Rule data). Many of the HPV chemicals have been sponsored by industry, and EPA hopes to have all HPV testing completed by 2004. The following chemicals in the Flexo CTSA are in the HPV challenge.

Table 2.9 Chemicals in the High Production Volume Challenge Program

Butyl acetate	2-Ethylhexyl diphenyl phosphate
Butyl carbitol	n-Heptane
C.I. Pigment Blue 15	1,6 Hexanediol acrylate
C.I. Pigment Blue 61	Hydroxypropyl acrylate
C.I. Pigment Green 7	Isobutanol
C.I. Pigment Red 48, barium salt	Isopropanol
C.I. Pigment Red 48, calcium salt	Paraffin wax
C.I. Pigment Yellow 14	Polyethylene glycol
Citric acid	Propanol
D&C Red No. 7	Propyl acetate
Dicyclohexyl phthalate	Propylene glycol methyl ether
Dioctyl sulfosuccinate, sodium salt	Propylene glycol propyl ether
Dipropylene glycol methyl ether	Resin acids, hydrogenated, methyl esters
Distillates, (petroleum), hydrotreated light	Solvent naphtha (petroleum), light aliphatic
Distillates, (petroleum), solvent-refined light paraffinic	Styrene
Erucamide	Tetramethyldecyndiol
Ethanol	Titanium isopropoxide
Ethanolamine	Trimethylolpropane ethoxylate triacrylate
Ethyl acetate	Trimethyolpropane triacrylate
Ethyl carbitol	Urea

Table 2.10 CTSA Chemicals Regulated Under TSCA

Chemical Name	Section 4	Section 8(a) PAIR	Section 8(d)	Section 12(b)
Ammonia		✔		
Butyl acetate	✔			✔
Butyl carbitol	✔			✔
Dicyclohexyl phthalate		✔	✔	
Dipropylene glycol methyl ether	✔	✔	✔	✔
Ethyl acetate	✔	✔	✔	✔
Ethyl carbitol		✔	✔	
2-Ethylhexyl diphenyl phosphate	✔	✔	✔	✔
n-Heptane	✔	✔	✔	✔
1,6-Hexanediol diacrylate		✔		
Hydroxypropyl acrylate		✔		
Isobutanol	✔	✔	✔	✔
Isopropanol		✔	✔	
Propylene glycol methyl ether		✔	✔	
Silicone oil		✔	✔	
Styrene		✔		
Urea		✔		

Clean Water Act

The Clean Water Act (CWA) protects the chemical, physical, and biological quality of surface waters (e.g., lakes or rivers) in the United States. The CWA regulates wastewater discharged directly into surface waters or into municipal sewer systems. Most printers discharge wastewater to municipal sewer systems, which also are known as Publicly Operated Treatment Works (POTWs).

National Pollutant Discharge Elimination System Program

Discharges of wastewater from point sources directly into a navigable water body are regulated under the National Pollutant Discharge Elimination System (NPDES) program

(CWA §402). This program applies to commercial and industrial facilities, as well as to POTWs. This program requires affected facilities to apply for a NPDES permit that is issued either by EPA or an authorized state agency.

The permits issued under NPDES contain industry-specific, technology-based, and water quality-based limitations on wastewater effluent. Generally, all facilities must meet limitations reflecting the best available control technology, regardless of the quality of receiving waters. Additionally, water quality-based limitations may also be required depending on the classification of the waters to which the effluent is discharged. For example, state and locally mandated water quality criteria may be designated to protect surface waters for aquatic life and recreation. In addition, NPDES permits specify the pollutant monitoring and reporting requirements for each regulated facility.

In addition, a storm water permit may be required if storm water is released to waters of the United States or to a municipal separate storm sewer system. In states in which EPA is the NPDES permitting authority, printers are eligible for the Multi-Sector General Permit (MSGP). In states where state agencies are authorized to execute NPDES permitting, requirements may be different or more stringent. A MSGP application requires a Storm Water Pollution Prevention Plan (SWPPP), which includes site maps showing drainage and outfall locations, an inventory of exposed materials, and pollution prevention Best Management Practices (BMPs). At least two days prior to the commencement of industrial activity, the facility would submit a Notice of Intent (NOI). Compliance with the MSGP may require visual examinations and analytical and compliance monitoring. If contaminated storm water is (or is planned to be) dischaged to a POTW, the POTW must be notified and permission to discharge obtained.

Printing facilities may be eligible for a conditional no exposure exclusion from storm water permitting. The exclusion is applicable if "all industrial materials and activities are protected by a storm resistant shelter to prevent exposure to rain, snow, snowmelt, and/or runoff," the facility operator submits a written *No Exposure Certification* form, and the operator allows the permitting authority to inspect the facility and make inspection reports publicly available upon request.

Wastewater Discharges to POTW

Printing facilities that discharge or otherwise introduce their wastewater to POTWs are not required to obtain a National Pollutant Discharge Elimination System (NPDES) permit. However, such facilities may be required to comply with regional and local discharge requirements and federal or local pretreatment standards, and obtain local permits. Such requirements are established by the local and regional sewerage authorities to prevent significant interference with the POTW. Certain requirements also prevent the pass-through of hazardous, toxic, or other wastes not removed by available treatment methods. A POTW may require commercial and industrial customers, including printers, to monitor wastewater, keep records, and notify the POTW of certain discharges.

A national pretreatment program (CWA §307(b)) regulates the introduction of pollutants to POTWs by industrial users. Pretreatment standards include general prohibitions and categorical industry standards (implemented on a nationwide basis), as well as local limits. General prohibitions involve pollutants that may not be introduced by any POTW users. These include the following materials:

- Pollutants that cause a fire or explosion hazard in the POTW
- Pollutants that will cause corrosive structural damage to the POTW
- Solid or viscous pollutants in amounts which will cause obstruction to the flow in the POTW
- Any pollutant, including oxygen demanding pollutants (BOD, etc) released in a discharge at a flow rate and/or pollutant concentration that will cause interference with the POTW
- Heat in amounts that will inhibit biological activity in the POTW
- Petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass-through
- Pollutants that result in the presence of toxic gases, vapors or fumes within the POTW in a quantity that may cause acute worker health and safety problems
- Any trucked or hauled pollutants, except at discharge points designated by the POTW.

No categorical pretreatment standards have been established for the printing industry. However, POTWs may establish local limits for customers.

Listed Chemicals

CTSA chemicals specifically regulated under the CWA (Table 2.11) are included in one of the following categories:

- *Hazardous substances* that are listed under Section 311 of the CWA have Reportable Quantity (RQ) thresholds; should a release of such a chemical occur above the threshold (or the effluent limitation established in a facility's NPDES or POTW permit), notice must be made to the federal government of the discharge. Four chemicals found in the inks used in this CTSA are hazardous substances.
- *Priority Pollutants* are 126 chemicals that must be tested for as a requirement of NPDES permits. One priority pollutant — surfactants (e.g., ethlyene glycol ethers) — is found in the inks used in this CTSA.

Table 2.11 CTSA Chemicals Regulated Under CWA

Chemical	Hazardous Substance RQ (lbs.)	Priority Pollutant
Ammonia	100	
Ammonium hydroxide	1000	
Butyl acetate	5000	
Styrene	1000	
Surfactants (e.g., ethylene glycol ethers)		✔

Safe Drinking Water Act

The goal of the Safe Drinking Water Act (SDWA) is to ensure that drinking water is safe for the public. Under the SDWA, EPA has established national primary drinking water regulations. The primary regulations set maximum concentrations for substances found in drinking water that can adversely affect human health. Flexographic chemicals that may be regulated by SDWA include barium and styrene.

Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or more commonly known as Superfund) was enacted in 1980. CERCLA is the Act that created the Superfund hazardous substance cleanup program and set up a variety of mechanisms to address risks to public health, welfare, and the environment caused by hazardous substance releases.

Two important components of CERCLA are the (1) hazardous substance release notification requirements, and (2) establishment of the parties that are liable for response costs for removal or remediation of a release. Substances defined as hazardous under CERCLA are listed in 40 CFR 302.4. Under CERCLA and other acts, EPA has assigned a Reportable Quantity (RQ) to most hazardous substances; regulatory RQs are either 1, 10, 100, 1000, or 5000 pounds (except for radionuclides). If a release greater than the RQ occurs, a person in charge of the facility must immediately notify the National Response Center to help EPA identify sites that potentially warrant a response action. If EPA has not assigned an RQ to a hazardous substance, typically its RQ is one pound. Eight chemicals used in this CTSA have RQs, and are provided in Table 2.12.

Table 2.12 CTSA Chemicals Regulated Under CERCLA

Chemical	RQ (lbs.)
Ammonia	100
Ammonium hydroxide	1000
Butyl acetate	5000
Butyl carbitol[a]	✔
Dicyclohexyl phthalate[b]	✔
Ethyl acetate	5000
Ethyl carbitol[a]	✔
Isobutanol	5000
Styrene	1000

[a] This chemical is part of the glycol ethers broad category; a reportable quantity is not listed.
[b] This chemical is part of the phthalate esters broad category; a reportable quantity is not listed.

Emergency Planning and Community Right-to-Know Act

In 1986, Congress passed the Emergency Planning and Right-to-know Act (EPCRA) as part of the Superfund Amendments and Reauthorization Act (SARA). Three provisions of EPCRA may be of concern for printers: emergency notification, community right to know reporting, and the Toxic Release Inventory (TRI).

EPCRA Section 302 defines and regulates certain extremely hazardous substances. If quantities of these chemicals at a facility exceed the threshold planning quantities, the facility must notify the state and local emergency planning committees. These chemicals are also regulated by EPCRA Section 304, which requires facilities to report releases in excess of reportable quantities to the same state and local authorities, and to the local fire department. One chemical used in this CTSA, ammonia, is listed as an extremely hazardous substance (EHS). EPCRA 304 also requires facilities to notify the state and local authorities of release of CERCLA hazardous substances so that state and local governments and citizens can be informed of potential hazards.

EPCRA Sections 311 and 312 require facilities to report inventory information on the hazardous chemicals present on-site. Facilities are regulated under these provisions if they are regulated under OSHA's Hazard Communication Standard and exceed established thresholds for hazardous chemicals as defined in 29 CFR 1910.1200(c) at any one time. Facilities using hazardous chemicals must submit reports containing information on each hazardous chemical's identity, physical and health hazards, and location to state and local emergency planning committees and the local fire department. Reporting thresholds are 10,000 pounds for a compound that is not classified as an EHS, and 500 pounds or the chemical's threshold planning quantity (TPQ), whichever is lower, for an EHS. The EHS used in the CTSA, ammonia, has a reporting threshold of 500 pounds.

Under EPCRA Section 313, a facility in a covered SIC code (of which printing is one), that has 10 or more full-time employees or the equivalent, and that manufactures, processes, or otherwise uses a toxic chemical listed in 40 CFR Section 372.65 above the applicable reporting threshold, must either file a toxic chemical release inventory (TRI) reporting form (EPA Form R), or if applicable, an annual certification statement (EPA Form A). The Form R details a facility's release and other waste management activities of these listed toxic chemicals, including those releases specifically allowed by EPA or state permits. Except for the specific exemptions listed in 40 CFR372.45(d), printers should be aware that suppliers of products containing TRI chemicals above certain *de minimis* (minimum) concentrations are required to notify each customer (to whom the mixture or trade name product is sold or otherwise distributed from the facility) of the name of each listed toxic chemical and the percent by weight of each toxic chemical in the mixture or trade name product. Table 2.13 lists the six chemicals used in this CTSA that must be reported to TRI when annual use exceeds the TRI thresholds. The annual reporting thresholds for these chemicals, none of which are EPCRA Section 313 persistent, bioaccumlative toxins (PBTs),[a] are 25,000 pounds for manufacture and process, and 10,000 pounds for otherwise use.

[a] Recently promulgated rules lowered the reporting thresholds for compounds that are persistent, bioaccumlative toxins in the environment. Information can be obtained by contacting the RCRA, Superfund, and EPCRA Hotline at the number and website listed at the end of this section.

Table 2.13 CTSA Chemicals Regulated Under EPCRA

Chemical	EPCRA 302 Extremely Hazardous Substances	EPCRA 313 TRI Chemicals
Ammonia	✔	✔[a]
Barium		✔
Butyl carbitol		✔
Ethyl carbitol		✔
Isopropanol[b]		✔
Styrene		✔

[a]Includes anhydrous ammonia and aqueous ammonia from water dissociable ammonium salts and other sources; 10% of total aqueous ammonia is reportable.
[b]Processors and users of isopropanol are not required to report it. It is reportable by manufacturers using the strong acid process.

Occupational Safety and Health Act

The Occupational Safety and Health Administration (OSHA) was established to reduce occupational health hazards. OSHA regulations outline the educational and informational resources that a printer must utilize to assure the safe use of chemicals and the health of employees, including the following basic requirements:

- Material Safety Data Sheets (MSDSs) for certain hazardous chemicals must be provided by suppliers and maintained in-house for use by employees. For chemicals stored and used in amounts in excess of threshold levels, copies of MSDSs must be submitted to state and local emergency planning agencies and the local fire department.
- If a chemical is claimed to be proprietary, the appropriate information must be supplied to the designated health official.
- All containers must be properly labeled.
- A Job Safety and Health Protection workplace poster that indicates employee rights and responsibilities must be posted in a prominent place.
- A safety training program must be developed, and all employees must be trained.
- Facilities must submit an annual report indicating the aggregate amount of chemicals (above threshold quantities) used at their facilities, classified by hazard category.

The Occupational Safety and Health Act (OSH Act) also requires the use of personal protection equipment (PPE) for specific situations. These may involve the use of gloves and goggles when working with certain solvents and inks. Other requirements relevant to printers include the installation of emergency eye wash stations in areas where eye irritants are used, and the development of a hearing conservation program if noise levels are equal to or exceed an eight-hour time weighted average of 85 decibels.

OSHA lockout/tagout regulations require the control of energy to equipment during servicing and maintenance. To prevent a machine from unexpectedly energizing, a facility must develop a plan to ensure that the energy source of a machine is locked out (with a locking device) or tagged out (with a prominent sign and fastener) when servicing or maintenance is being performed. For routine servicing (such as minor cleaning), printers may use effective alternative protection such as the "inch-safe-service" method which allows energization of the press to inch it forward for servicing purposes as long as, at a minimum, a stop/safe/ready function is available at designated control stations and other requirements are followed.

The OSH Act also governs the exposure of workers to chemicals in the workplace. OSHA has established permissible exposure limits (PELs) for air contaminants, which are regulatory limits on the amount or concentration of a substance in the air (29 CFR 1910.1000 Subpart Z) based on an 8-hour time weighted average. (PELs also may have a skin designation.) Other chemical exposure concentrations potentially used for regulation by OSHA include ceiling limits and short term exposure limits.

Table 2.14 Flexography Federal Regulations Chemical Worksheet

Regulation	Affected Chemicals
Clean Air Act (CAA)	
112(b) Hazardous Air Pollutant	Butyl carbitol Ethyl carbitol Styrene
112(r) Risk Management Plan	Ammonia (in concentrations greater than 20%)
Resource Conservation and Recovery Act (RCRA)	
Characteristic Wastes (D Wastes)	Barium (D005) Ethyl acetate (D001) Ignitable solvent-based inks (D001) Isobutanol (D001) Any other waste that exhibits ignitability, corrosivity, reactivity, or toxicity as defined by RCRA
Non-specific Source Wastes (F Wastes)	Ethyl acetate (F003) Isobutanol (F005)
Specific Unused Chemicals (U Wastes)	Ethyl acetate (U112) Isobutanol (U140)
Toxic Substances Control Act (TSCA)	
Section 4	Butyl acetate Butyl carbitol Dipropylene glycol methyl ether Ethyl acetate 2-Ethylhexyl diphenyl phosphate n-Heptane Isobutanol
Section 8(a) PAIR	Ammonia Dicyclohexyl phthalate Dipropylene glycol methyl ether Ethyl acetate Ethyl carbitol 2-Ethylhexyl diphenyl phosphate n-Heptane 1,6 Hexanediol diacrylate Hydroxypropyl acrylate Isobutanol Isopropanol Propylene glycol methyl ether Silicone oil Styrene Urea

Table 2.14 Flexography Federal Regulations Chemical Worksheet (continued)

Regulation	Affected Chemicals
Section 8(d)	Dicyclohexyl phthalate Dipropylene glycol methyl ether Ethyl acetate Ethyl carbitol 2-Ethylhexyl diphenyl phosphate n-Heptane Isobutanol Isopropanol Propylene glycol methyl ether Silicone oil
Section 12(b)	Butyl acetate Butyl carbitol Dipropylene glycol methyl ether Ethyl acetate 2-Ethylhexyl diphenyl phosphate n-Heptane Isobutanol
Clean Water Act (CWA)	
Hazardous Substances (Reportable Quantities)	Ammonia (100 lbs.) Ammonium hydroxide (1000 lbs.) Butyl acetate (5000 lbs.) Styrene (1000 lbs.)
Priority Pollutants	Surfactants
Safe Drinking Water Act (SDWA)	
National Primary Drinking Water Regulations	Barium Styrene
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	
Reportable Quantities (RQs)	Ammonia (100 lbs.) Ammonium hydroxide (1000 lbs.) Butyl acetate (5000 lbs.) Butyl carbitol (RQ not listed) Dicyclohexyl phthalate (RQ not listed) Ethyl acetate (5000 lbs.) Ethyl carbitol (RQ not listed) Isobutanol (5000 lbs.) Styrene (1000 lbs.)

Table 2.14 Flexography Federal Regulations Chemical Worksheet (continued)

Regulation	Affected Chemicals
Emergency Planning and Community Right-to-Know Act (EPCRA)	
Extremely Hazardous Substances	Ammonia
TRI Chemicals	Ammonia (10% of total aqueous ammonia) Barium Butyl carbitol Ethyl carbitol Isopropanol Styrene
Occupational Safety and Health Act (OSHA)	
Personal Exposure Limits (PELs)	Ammonia Barium 2-Butoxyethanol Butyl acetate Dipropylene glycol methyl ether Ethanol Ethanolamine Ethyl acetate n-Heptane Isobutanol Isopropanol Kaolin Propanol Propyl acetate Styrene

Additional Information on Printing-Related Regulations

GENERAL INFORMATION

Printers' National Environmental Assistance Center (PNEAC)
A website with links to compliance assistance and pollution prevention information and state-specific requirements
Website: www.pneac.org

Federal Environmental Regulations Potentially Affecting the Commercial Printing Industry (1994)
A short booklet that describes important points about the Clean Air Act, Clean Water Act, RCRA, etc., and how the printing industry is affected by each. Available from The Pollution Prevention Clearinghouse. Ask for Document EPA 744-B-94-001.
Telephone: 202-260-1023
Website: www.epa.gov/opptintr/library/libppic.htm

Government Printing Office (GPO)
The GPO website provides links to the full text of the Code of Federal Regulations (CFR), Federal Register notices for the past several years, and other resources.
Website: www.access.gpo.gov/nara/

INFORMATION ABOUT THE CLEAN AIR ACT

The **Clean Air Technology Center** (CATC)
A source of general information on air emissions-related technology.
Telephone: 919-541-0800
Website: www.epa.gov/ttn/catc

INFORMATION ABOUT THE RESOURCE CONSERVATION AND RECOVERY ACT

The **RCRA, Superfund & EPCRA Hotline** offers information and publications that are relevant to RCRA.
Telephone:800-424-9346
Website: www.epa.gov/epaoswer/hotline

RCRA in Focus: Printing
A short booklet that provides an overview of the federal regulations that the printing industry is required to follow and lists the printing industry wastes that are likely to be hazardous. Available from the RCRA, Superfund & EPCRA Hotline. Ask for Document EPA 530-K-97-007.

Understanding the Hazardous Waste Rules: A Handbook for Small Businesses, 1996 Update
A manual that is targeted to small quantity generators of hazardous wastes. The manual helps small businesses determine whether they generate hazardous waste and provides comprehensive information on how to comply with the federal hazardous waste regulations for small quantity generators. Available from the RCRA, Superfund & EPCRA Hotline. Ask for Document EPA 530-K-95-001.

INFORMATION ABOUT THE TOXIC SUBSTANCES CONTROL ACT

The **TSCA Assistance Information Service** (TSCA hotline) can provide information TSCA.
Telephone: 202-554-1404
Website: www.epa.gov/opptintr/chemtest

INFORMATION ABOUT THE CLEAN WATER ACT

The **Office of Water**
The Office of Water, especially the Office of Wastewater Management, can be contacted for information on Clean Water Act provisions that relate to the printing industry.
Telephone: 202-260-5700
Website: www.epa.gov/OW

INFORMATION ABOUT THE SAFE DRINKING WATER ACT

The **Safe Drinking Water Hotline** can provide information on issues related to the Safe Drinking Water Act.
Telephone: 800-426-4791
Website: www.epa.gov/OGWDW/

INFORMATION ABOUT THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT

The **RCRA, Superfund & EPCRA Hotline** offers information and publications that are relevant to CERCLA.
Telephone:800-424-9346
Website: www.epa.gov/epaoswer/hotline

The **Superfund Website** provides general information on CERCLA.
Website: www.epa.gov/superfund

INFORMATION ABOUT THE EMERGENCY PLANNING AND RIGHT-TO-KNOW ACT

The **Chemical Emergency Preparedness and Prevention Office** website
Website offers information on the emergency response aspects of EPCRA, which are administered under the Chemical Emergency Preparedness and Prevention Office.
Website: www.epa.gov/swercepp/

The **Toxics Release Inventory** website
Provides information on the Toxics Release Inventory reporting requirements, which are implemented by the Office of Pollution Prevention and Toxics.
Website: www.epa.gov/opptintr/tri/index.html

The **RCRA, Superfund & EPCRA Hotline** offers information and publications that are relevant to EPCRA.

Telephone:800-424-9346

Website: www.epa.gov/epaoswer/hotline

INFORMATION ABOUT THE OCCUPATIONAL SAFETY AND HEALTH ACT

The **Occupational Safety and Health Administration (OSHA)** website
Provides information on the Occupational Safety and Health Act, OSHA regulations, standards, interpretations, and other information.

Website: www.osha.gov/

INFORMATION ABOUT THE DEPARTMENT OF TRANSPORTATION

The **Department of Transportation (DOT) Hazardous Materials Information Center** provides information about transporting hazardous materials.

Telephone: 800-467-4922

Website: http://hazmat.dot.gov/

2.4 PROCESS SAFETY

Procedures for safely preparing, operating, and cleaning press equipment help to avoid serious injuries and health problems to employees. An effective process safety program identifies workplace hazards and seeks to eliminate or reduce their potential for harm. Chemicals used in the flexographic printing process present safety hazards to workers and the facility; therefore they must be handled and stored properly using appropriate personal protective equipment and safe operating practices.

The U.S. Department of Labor and the Occupational Safety and Health Administration (OSHA) have established safety standards and regulations to assist employers in creating a safe working environment and protect workers from potential workplace hazards. In addition, individual states may also have safety standards regulating chemical and physical workplace hazards for many industries. Federal safety standards and regulations affecting the flexographic printing industry can be found in the Code of Federal Regulations (CFR) Title 29, Part 1910 and are available by contacting the local OSHA field office. State and local regulations are available from the appropriate state office.

Reactivity, Flammability, Ignitability, and Corrosivity of Flexographic Ink Chemicals

Table 2.15 lists four safety hazard factors for the nine ink product lines that were tested in the performance demonstrations, and Table 2.16 summarizes the safety hazards by ink system. (Where available, the reactivity and flammability values were extracted directly from Section One of the Material Safety Data Sheet (MSDS), which contains the National Fire Protection Association (NFPA) values for these factors.) Printers should be aware of the safety hazards for all chemicals used and stored in a facility, should post the relevant MSDSs as required, and should consider whether ink products with lower safety ratings are available and suitable.

For **reactivity**, NFPA ranks materials on a scale from 0 to 4, with 0 being the safest:

0 — materials that are normally stable, even under fire exposure conditions, and that do not react with water; normal fire fighting procedures may be used.

1 — materials that are normally stable but may become unstable at elevated temperatures and pressures, as well as materials that will react (but not violently) with water, releasing some energy; fires involving these materials should be approached with caution.

2 — materials that are normally unstable and readily undergo violent chemical change, but are not capable of detonation; this includes materials that can rapidly release energy, materials that can undergo violent chemical changes at high temperatures and pressures, and materials that react violently with water. In advanced or massive fires involving these materials, fire fighting should be done from a safe distance from a protected location.

3 — materials that, in themselves, are capable of detonation, explosive decomposition, or explosive reaction, but require a strong initiating source or heating under confinement; fires involving these materials should be fought from a protected location.

4 — materials that, in themselves, are readily capable of detonation, explosive decomposition, or explosive reaction at normal temperatures and pressures. If a material

having this Reactivity Hazard Rating is involved in a fire, the area should be immediately evacuated.

For the CTSA inks, all inks except the UV product lines were rated as completely non-reactive. One UV product line was given a rating of 1, and the others did not have a rating.

For **flammability**, NFPA ranks materials also on a scale from 0 to 4, with 0 being the safest:

0 — materials that will not burn.

1 — materials that must be preheated before ignition will occur and whose flash point exceeds 200 °F (93.4 °C), as well as most ordinary combustible materials.

2 — materials that must be moderately heated before ignition will occur and that readily give off ignitible vapors.

3 —flammable liquids and materials that can be easily ignited under almost all normal temperature conditions; water may be ineffective in controlling or extinguishing fires in such materials.

4 — flammable gases, pyrophoric liquids, and flammable liquids. The preferred method of fire attack is to stop the flow of material or to protect exposures while allowing the fire to burn itself out.

Flammability ratings for the CTSA ink product lines ranged widely. Both solvent-based inks were rated at 3, and water-based inks received ratings ranging from 0 to 3. One UV product line was given a rating of 1, but the others were unrated.

For **ignitability**, the inks are classified as either ignitable (y) or not ignitable (n). Ignitability is based on the flash point of the ink product line, which is the lowest temperature at which it can be ignited. A chemical is considered ignitable if it is a liquid, other than an aqueous solution containing less than 24% alcohol by volume and has a flash point less than 60°C (140 °F).[39] For the CTSA product lines, only the two solvent-based inks were rated as ignitable.

For **corrosiveness**, the inks are classified as either corrosive (y) or not corrosive (n). Corrosiveness was determined based on the pH of the product.[40] A chemical is corrosive if it is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5. This information was not available for any product lines except one, which was rated as non-corrosive.

Table 2.15 Safety Hazard Factors for CTSA Ink Product Lines[a]

Product line	Formulation (Color)	Reactivity	Flammability	Ignitability	Corrosivity
Solvent-based #S1	All	0	3	y	
Solvent-based #S2	All	0	3	y	
Water-based #W1	Blue, green	0	3	n	
	White, cyan	0	2	n	
	Magenta	0	1	n	
Water-based #W2	Blue, green, white	0	0	n	n
	Cyan, magenta	0	1	n	
Water-based #W3	All	0	1	n	
Water-based #W4	Blue	0	0	n	
		0	2	n	
		0	3	n	
	Green	0	2	n	
		0	2	n	
		0	3	n	
	White	0	2	n	
	Cyan	0	0	n	
		0	3	n	
	Magenta	0	2	n	
UV-cured #U1	All			n	
UV-cured #U2	All	1	1	n	
UV-cured #U3	All			n	

[a] A blank cell indicates that there was not enough information available to develop a safety hazard factor ranking. For inks that were blended and therefore have more than one MSDS, the ratings for all components in each formulation are given.

Table 2.16 Summary of Safety Hazard Factors by Ink System

Ink system	Reactivity	Flammability	Ignitability	Corrosiveness
Solvent-based	0	3	y	ND[a]
Water-based	0	0-3	n	[b]
UV-cured	[c]	[d]	n	ND[a]

[a] No data
[b] Incomplete data — three formulations of one product line were not corrosive.
[c] Incomplete data — all formulations of one product line were given reactivity levels of 1.
[d] Incomplete data — all formulations of one product line were given flammability levels of 1.

The following observations can be noted from the tables:

- All of the solvent- and water-based inks had reactivity levels of zero. One UV-cured ink (#U2) had a reactivity level of one; the reactivity of other UV-cured inks was unknown.

- Flammability was more of a concern for some inks than others. All of the solvent-based inks had flammability levels of three. Some of the water-based inks (Water-based inks #W2 and #W3) had flammability levels of zero or one. However, some formulations of Water-based inks #W1 and #W4 had flammability levels of two or three. The flammability levels for UV-cured ink #U2 was one; the flammability of the other UV-cured inks were not known.

- Ignitability was a concern primarily for solvent-based inks.

- Although information for corrosiveness was sparse, the water-based inks for which information was available were listed as not corrosive.

Process Safety Concerns

Exposure to chemicals is just one of the safety issues that flexographic printers may have to deal with during their daily activities. By establishing and following proper safeguards and practices, printers can benefit in three ways: increased worker safety, lower insurance rates, and fewer work days missed due to accidents and injuries.

To maintain a safe and efficient workplace, employers and employees need to understand the importance of establishing safety procedures and using appropriate safeguards. The most important safety practices include the following:

Training

A critical element of workplace safety and an efficiently running press is a well-educated workforce. To help achieve this goal, the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard requires that all employees be trained in the use of hazardous chemicals to which they may be exposed. Training may be conducted either by facility staff or by outside parties who are familiar with the flexography process and the pertinent safety concerns. The training should be held for each new employee, and all employees should have retraining when necessary (for example, if new equipment is installed or new ink types are used) or on a regular schedule. The training program should explain the types of inks, solvents, cleaning compounds, and other chemicals used, and precautions for handling or storing them; when and how personal protective equipment (PPE) should be worn; the need for other safety features such as equipment guards and their proper use; and how to maintain equipment in good operating condition.

Contingency Plan for Chemical Spills and Emergencies

Most states require manufacturing facilities, including flexographic printing facilities, to establish a contingency plan in the event of an accidental chemical release. Having a plan in place can reduce injuries to employees, help protect the community and environment, and minimize downtime. The plan should include the following:

- a list of chemicals in the facility
- how the chemicals are stored and used

- information on the likely cause, nature, and route of a chemical release
- emergency response devices and procedures including alarm systems, evacuation plans, and arrangements with local hospitals, police, and fire departments
- contact information for the facility emergency coordinators
- emergency equipment information, such as the location of fire extinguishers and spill control kits.[41]

Electrical Grounding

Grounding is an important safety precaution when using machinery. When conductive material, like a steel central impression drum, is not grounded, the conductor may generate and/or store electricity. Non-conductive or ungrounded conductive materials become electrostatically charged by friction.[42] Static may be generated when the web is unwinding, when the web leaves the rollers, or by friction from shoes and clothing. Static is also increased by low humidity.[43] Static may result in sparks that can cause explosions and electrical interference. Proper grounding is the simplest way to control static.

Storing Chemicals

Chemicals that are ignitable or flammable should be labeled accordingly and stored in the appropriate storage space. Chemicals that are incompatible with other chemicals or that require special precautions during use should also be appropriately labeled and stored. For example, solvents and solvent-based inks should be stored in ventilated, explosion-proof rooms. Since some of the chemicals used in the press room may be flammable, the facility should be inspected periodically by the local fire marshall to ensure that the chemicals are stored properly and ventilated, thus reducing the potential for a fire.

Storing Rags and Towels

Rags and towels that are used to wipe up chemicals or clean presses may be considered hazardous waste by EPA and state and local agencies if they contain specified hazardous chemicals in sufficient amounts. These towels should be stored and disposed of in accordance with federal, state, and local regulations. If uncertain about whether or not the shop's used rags or towels require special treatment as hazardous waste, a printer should contact the state environmental agency or state technical assistance program.

Preventive Worker Behavior

Personal safety considerations are also the responsibility of the worker. Workers should be discouraged from eating or keeping food near presses or chemicals. Since presses contain moving parts, workers should also refrain from wearing jewelry or loose clothing that may become caught in the machinery and cause injury to the worker. In particular, the wearing of rings or necklaces may lead to injury. Workers with long hair should pull their hair back or wear a hair net to prevent the hair from getting caught in the machinery.

Material Safety Data Sheets

Since flexographic printing requires the use of a variety of chemicals, it is important that workers know and follow the correct procedures for handling the chemicals. Much of the information about the use, disposal, and storage of chemicals may be obtained from the Material Safety Data Sheet (MSDS) provided by the manufacturer for each ink product line, cleaner, and other chemicals. The MSDS also recommends the appropriate personal protective equipment for handling a particular chemical. The MSDS for each chemical used should be placed in an easily accessible location in the vicinity of the press room.

Personal Protective Equipment (PPE)

OSHA has developed several PPE standards that are applicable to the printing industry. These standards address general safety requirements (29 CFR Part 1910.132), the use of eye and face protection (Part 1910.133), head protection (Part 1910.135), foot protection (Part 1910.136), and hand protection (Part 1910.138). The standards for eye, face, and hand protection are particularly important for printers who have frequent contact with chemicals (including solvents, dispersants, surfactants, and inks) that may irritate or harm the skin and eyes.

In order to prevent or minimize exposure to such chemicals, workers should be trained in the proper use of personal protective equipment. For many chemicals, appropriate equipment includes goggles, aprons or other impervious clothing, and gloves. In some printing facilities with loud presses, hearing protection may be recommended or required.

Equipment Guards

In addition to the use of proper personal protective equipment for all workers, OSHA has developed safety standards that apply to the actual equipment used in printing facilities. These machine safety guards are described in 29 CFR Part 1910.212 and are applicable to all sectors of the printing industry, including flexography. Barrier guards, two-hand trip devices, and electrical safety devices are among the safeguards recommended by OSHA. Safeguards for the normal operation of press equipment are included in the standards for mechanical power-transmission apparatus (29 CFR Part 1910.219) and include belts, pulleys, flywheels, gears, chains, sprockets, and shafts.

The National Printing Equipment and Supply Association has available copies of the American National Standard for Safety Specifications for Printing Press Drive Controls. These safety recommendations address the design of press drive controls specifically, as well as safety signaling systems for printing presses. Printers should be familiar with the safety requirements included in these standards and should contact their local OSHA office or state technical assistance program for assistance in determining how to comply with them.

OSHA also has a lockout/tagout standard (29 CFR part 1910.147). This standard is designed to prevent the accidental start-up of electric machinery during cleaning or maintenance operations. This standard may pose particular problems for flexographic printers during minor, routine procedures that require frequent stops (e.g., cleaning the press or on-press maintenance). For such cases, OSHA has granted an exemption for minor servicing of machinery provided the equipment has other appropriate safeguards, such as a stop/safe/ready button which overrides all other controls and is under the exclusive control of the worker performing the servicing. Such minor servicing of printing presses has been determined to include clearing jams, minor cleaning, lubricating, adjusting operations, plate changing tasks, paper webbing, and roll changing. Rigid finger guards should also extend across the rolls, above and below the area to be cleaned. Proper training of workers is required under the standard whether lockout/tagout is employed or not. For further information on the applicability of the OSHA lockout/tagout standard to printing operations, printers should contact their local OSHA field office.

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